FOS Optical Focus and Resolution

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Abstract

Line spectra, obtained following the final FOS detector alignment in August 1988, are examined to determine line widths and assess the optical focus for all dispersers (except G130H) and the camera, on both sides of the FOS. The detector focus adjustment is found to be satisfactory and probably nearly optimal. Some recommendations for wavelength calibration line identification are made. Poor performance of the filter-grating wheel on the red side is also inferred.

I. Introduction

Final installation and alignment of the FOS flight Digicon detectors were performed at LMSC in August, 1988, after attachment of newly-developed stainless steel heat pipes. The alignment testing utilized an external Pt-Cr/Ne hollow cathode lamp, spectra from which were used to determine the detector alignment error in X (dispersion), Z (focus), and rotation about the X and Y (cross-dispersion) axes, Theta-X and Theta-Y. A tungsten-halogen (FEL) lamp was also used for the alignment; its continuous spectrum permitted rapid assessment of the alignment in Y and Theta-Z. Errors in Y and Theta-Z have little effect on the spectrograph resolution, and are not treated in this report. The alignment in X determines the wavelength coverage of each disperser, and has been previously analyzed by Kriss, et al. (CAL/FOS–054). This report presents analysis of external hollow cathode lamp spectra, obtained after the final FOS rework, as used to determine the focus alignment, and resulting spectral resolution, for each of the FOS filter/grating wheel elements.

II. The Observations

The alignment check data were obtained with STOL procedure YALIGN. A 90% Pt, 10% Cr hollow cathode lamp, similar to the onboard wavelength calibration sources, was mounted on a special attachment to the ASTOS, with a fused silica lens mounted near its window, to concentrate the beam at the FOS apertures. The mounting permitted adjustment of the lamp in tilt and translation, so that the beam could be made to fill the FOS optics. This adjustment was performed by straightforward visual inspection of the lamp beam as it passed through the FOS optical train. Once the lamp was aligned, tests showed that the ASTOS could be removed and reinstalled, on either side of the FOS, without requiring further adjustment. The lamp was operated at several currents to achieve suitable output flux levels: the current was set at 10 mA for all measurements on the B side of the FOS, at 30 mA for all disperser measurements on the A side, and at 2 mA for the camera mirror data on the A side. A MgF_2 diffuser, ground to a nominal 100 micron roughness on both sides, was placed over the FOS entrance port for the A side measurements; this was required in order to maintain the flux at low enough levels in the strong, red neon lines, while maintaining sufficient brightness in the cathode lines (to keep exposure times short). The neon line fluxes increase roughly linearly with lamp current, while the cathode lines brighten much more rapidly, up to about 30 mA. No diffuser was required on the B side, since the red neon lines are undetected by the blue digicon.

All spectra were obtained with 8 X-steps and normal overscanning, through the smallest (A4-lower, or 0.1-PAIR-B) aperture. The red detector was operated at the normal, zero focus current, voltage (21.4 kV), while the blue detector was operated at reduced voltage (18.4 kV), to minimize glow discharge at the front of the detector. Measurements were made with all appropriate FGW elements; the G130H grating (on the blue side) could not be measured, since the data were obtained in air.

III. Optical Resolution Measurement

The optical focus was assessed in a very straightforward manner: spectral lines were selected to cover the full accessible spectral range for each disperser and their full width at half of the peak flux above the underlying pseudo-continuum (FWHM) was measured. Because the line density is quite high, particularly in the near UV, much blending occurs, requiring subjective estimation of the baseline for many FWHM measurements. Where possible, lines were selected to be relatively free of blending; this was aided by use of an atlas of very high resolution spectra of a Pt/Ne hollow cathode lamp produced at the National Institute of Standards and Technology (NIST) by Reader, et al. (1989). However, the NIST spectra cover only the spectral range below 4100Å, and do not include the contribution from the Cr lines present in the FOS lamps. Hence, many of the measurements represent upper limits to the true width of the line spread function, since the underlying pseudo-continuum was conservatively estimated. All measurements were made directly; no attempt was made to determine the line widths with spectrum modelling or simulation.

A summary of the results is presented in Table 1, which lists the mean FWHM and standard deviation for each disperser/detector combination. Detailed results are presented in Table 2, which lists the line center and FWHM in diodes, along with the vacuum wavelength and its source reference, for each measured line. Figures 1a-o show several representative lines for each disperser/detector, and indicate the spectral range and resolving power. Figure 2 indicates the FWHM of the camera mirror image profiles.

IV. Discussion

a) Optical Focus Assessment

Examination of Table 1 shows that, for most FOS configurations, the mean line (or image) width is less than a diode spacing, thereby exceeding the resolving power specification. However, there are several exceptions that merit some discussion. The line widths produced by L15 grating were measured to be somewhat in excess of a diode, for both detectors. This result is probably somewhat in error, due to the low dispersion and high line density, and the consequential difficulty in selecting unblended lines or determining the appropriate pseudo-continuum level underlying the measured lines. Hence, since the continuum was subjectively estimated in a conservative manner (as low as could be construed as consistent with the surrounding spectrum), and close blends were necessarily included in the sample, the measured FWHM values should generally be taken as upper limits. The line with the least likelihood of significant blending (Pt I 2144.9), shows the minimal FWHM, which is well below a diode on the Blue side, and just over a diode on the Red side, significantly narrower than the other measured lines.

Similar arguments apply to the Prism measurements. The wide range in FWHM must result from measurement error, and this is strongly biased toward overestimation of the line widths. The Prism line measurements were generally restricted to the shorter wavelengths, where the dispersion permitted some attempt at selection of isolated lines; one long wavelength blend was measured on the Blue side at .94 diode FWHM. Again, the measurement of highest confidence (λ 2144.9) indicates that the true resolution easily exceeds the specification, on both sides.

The H78 grating focus was found, during the alignment procedure, to be relatively 'soft', and also somewhat 'inside' (i.e., detector closer to the grating) that of the other dispersers. The H19 grating focus was at the opposite extreme of the focus range, lying 'outside' the mean focus of the other dispersers, on the Red side. Thus the optimal location of the detector required a compromise; the selected position was weighted slightly toward the optimal H78 focus, since the H19 spectral range is not fully covered with the red detector (as it is with the blue detector).

The detectors photocathodes are apparently very near the optimal focal planes. Because the dispersers are not parfocal (owing to imperfect grating alignment: it is not possible to achieve optimal alignment on both sides, given the mechanical properties of the FGWA), a compromise focal position was determined during the detector alignment. This position yields spectral resolution that surpasses the FWHM=1 diode specification for most configurations.

b) Filter-Grating Wheel Non-repeatability

During the examination of the spectra to select 'clean' lines, it became apparent that, in a number of cases, the wavelength scale assigned using the normal IDL data reduction tool (YREDUCE) was in error by a large fraction of a diode. The dispersion coefficients used for the wavelength assignments were obtained from data taken within hours of the YALIGN data, and resulted in fits to the data with very small (several hundredths of a diode) RMS errors. Since the discrepant offsets were observed for only some of the dispersers, they cannot be ascribed to a shift in the detector between the wavelength cal and YALIGN measurements, but must result from filter/grating wheel (FGW) non-repeatability. The degree of non-repeatability observed was considerably larger than expected, based on FGW testing performed on a number of occasions in the previous three years, but almost exclusively on the B side of the FOS.

A further analysis of all applicable data obtained in August, 1988, indicated that the FGW repeatability on the B side was consistent with previous tests, but that the positioning errors were likely to be as much as three times as large on the A side. Special testing was therefore requested and performed at LMSC in May 1989 to investigate the magnitude and cause of this effect; the results are documented in CAL/FOS–060 (Hartig, 1989). Briefly, it was found that use of the A side FGW motor (which was selected when the red detector was used) results in poor repeatability. Additional testing in June 1989 showed that FGW operation with the A motor in the *reverse* direction does not significantly improve the performance. Hence, the B FGW motor will always be selected (until it fails) for flight operations.

c) Wavelength Calibration Considerations

In the process of selecting useful lines for the focus assessment, a number of lines that were previously identified for use as wavelength standards by Sirk and Bohlin (CAL/FOS–026) were found to be significantly blended. Also, some additional, well-isolated lines were selected to fill in gaps in the spectral coverage that may be useful for determining the dispersion coefficients. Tables 3 and 4 list both the 'rejected' and supplemental lines that were identified, and should be used in conjunction with Table 2 of CAL/FOS–026. However, no attempt has been made to determine the residual wavelength fitting errors for the additional lines; if these lines are included in wavelength calibration fits, the residuals should be examined carefully.

The 'lines' listed in Table 4 for the G650L grating and the prism are actually close blends: at low dispersion there are very few truly isolated lines available. Nevertheless, because of their relatively narrow profiles, the identified features may be useful for wavelength calibration once their wavelengths are well determined, especially if it is found that the relative strengths of the lines constituting these blends are reasonably stable. The listed approximate wavelengths were estimated from the dispersion constants given by Kriss, et al. (1988).

Although the Reader, Acquista and Sansonetti measurement of a Pt/Ne lamp was used as the primary reference in selecting the lines in Table 4, all the chosen lines were checked for possible Cr line blending.

Several typographical errors and mis-identifications were also found in CAL/FOS–026. We list these here, to avoid future confusion:

1. In the line list for H27 Red, on page 21, the air wavelength 2626.031 should read 2628.031. It is correctly identified in Figure 2j.
2. In Figure 2c and 2j, for H27 Blue and Red, line 2762.92 is mislabeled. The line near diode 255 (the leftmost of a group of three lines) should be labeled 2762.92, instead of the middle line of the group (near diode 257).
3. In Figure 2e, for H57 Blue, the lines labeled 5264.16, 5330.78 and 5400.56 are mis-identified. See Figure XXX, for the correct labeling.
4. In Figures 2h and 2p, for the Prism, the feature labeled 5208.5 is actually a blend of Cr lines, the intensity-weighted mean wavelength is more accurately 5206.93.
5. In Figure 2k, for H40 Red, the line labeled 3619.16 should be 3919.16.

References

Hartig, G. 1989. CAL/FOS–060, *FOS Filter-Grating Wheel Repeatability: Dependence on Motor Selection.*

Kriss, G.A., Blair, W.P. and Davidsen, A.F. 1988. CAL/FOS–054 *Revised FOS Wavelength Calibration.*

Phelps, F. M. III 1982. *MIT Wavelength Tables, Volume 2: Wavelengths by Element.*

Reader, J., Acquista, N., and Sansonetti, C. 1988. *PLatinum/Neon Master List* National Bureau of Standards and Technology, Gaithersburg, MD. 29 June 1988 (unpublished).

Reader, J., Acquista, N., Sansonetti, C. and Sansonetti, J. 1989. *Spectrum of a Platinum/Neon Hollow Cathode Lamp from 1032 to 4100Å*, National Institute of Standards and Technology, Gaithersburg, MD. 10 March 1989 (unpublished).

Sirk, M. and Bohlin, R. 1986. CAL/FOS–026, *FOS Wavelength Calibration.*

Figure Captions

Figure 1. (a-o) Line spectra of an external Pt-Cr/Ne hollow cathode lamp, through the A4 lower aperture, obtained in air for each relevant FOS disperser/detector combination. Selected line profiles are also shown, with their FWHM (in diode widths) and resolving power indicated. The wavelength coverage (with normal overscanning) is shown below the wavelength axis.

Figure 2. Profiles of the camera mirror images obtained with an external Pt-Cr/Ne lamp through the A4 lower apertures, for each detector. The FWHM (in diode widths) is indicated.

Figure 3. Corrections to the line identifications shown in Figure 2e of CAL/FOS–026, for H57, Blue detector. Incorrect identifications are enclosed in parentheses.

Table 1
Summary of Mean Line Widths

Detector	FGWA Element	Mean FWHM (diodes)	σ (diodes)
Blue	H19	0.916	0.028
Blue	H27	0.940	0.046
Blue	H40	0.997	0.022
Blue	H57	0.932	0.018
Blue	L15	1.015	0.069
Blue	L65	0.935	0.024
Blue	PRISM	0.901	0.066
Blue	CAM	0.851	—
Red	H19	1.023	0.051
Red	H27	0.999	0.022
Red	H40	0.998	0.040
Red	H57	0.943	0.019
Red	H78	1.006	0.022
Red	L15	1.094	0.045
Red	L65	0.962	0.016
Red	PRISM	1.025	0.055
Red	CAM	0.900	—

Table 2. Line Width Measurements

DISPERSER	VACUUM	REF	--RED SIDE-- DIODE	FWHM	--BLUE SIDE-- DIODE	FWHM
G190H	1907.494	A	279.92	1.092	227.44	0.957
	1911.710	A	277.03	1.041	230.31	0.924
	1916.083	A	273.98	1.049	233.28	0.877
	1934.369	RAS	261.28	1.072	245.65	0.912
	1949.910	RAS	250.48	1.075		
	1954.744	RAS			259.53	0.915
	2008.406	RAS	209.62	1.040	295.99	0.908
	2015.584	RAS	204.61	1.036		
	2144.922	A	114.41	0.988	388.96	0.886
	2175.352	A	93.15	0.936	409.77	0.869
	2210.193	RAS	68.86	0.923	433.53	0.926
	2269.540	RAS	27.50	0.988	474.38	0.952
	2293.085	A	11.08	1.041	490.63	0.946
G270H	2293.085	A			31.43	0.965
	2311.668	A	471.99	0.970	40.23	0.918
	2357.825	A	449.55	0.978	62.26	0.909
	2378.002	A	439.70	1.035	71.87	0.973
	2440.797	A			101.72	0.908
	2647.669	RAS	308.23	1.014	200.17	0.931
	2651.641	A	306.29	1.016	202.09	0.880
	2703.205	A	281.10	1.021	226.59	0.908
	2810.327	A			277.63	0.896
	2894.720	A			317.85	0.937
	2930.652	A	169.91	1.003	335.04	0.915
	2956.594	A			347.43	0.928
	2964.156	A			351.02	0.918
	2987.111	A	142.28	1.008		
	2998.845	A			367.58	0.931
	3089.126	A	92.41	0.977	410.81	0.925
	3219.139	A			473.41	0.987
	3245.086	A	16.18	0.970	485.92	1.019
	3298.689	A			511.94	1.069
G400H	3379.250	A	467.39	0.996	43.70	1.017
	3521.476	A	420.16	0.966		
	3543.912	A			97.19	1.015
	3606.349	A	391.95	0.982		
	3695.251	A	362.39	0.964		
	3744.954	A	345.88	0.974		
	3778.232	A	334.74	0.966	173.26	0.968
	3909.867	A	290.91	0.955	216.03	0.983
	3929.762	A			222.44	0.983
	3942.616	A	280.01	0.991	226.67	0.972
	3977.795	A			238.11	1.018
	3985.026	A			240.45	1.024
	3992.249	A			242.83	1.017
	4255.528	A	175.61	0.962	328.45	0.983
	4276.013	A	168.79	0.967	335.12	0.985
	4290.938	A	163.81	0.964	339.99	0.973
	4345.731	A	145.49	1.017		
	4352.993	A	143.13	1.003	360.20	1.028
	4372.508	A	136.52	1.069		

Table 2 (continued).

DISPERSER	VACUUM	REF	--RED SIDE-- DIODE	FWHM	--BLUE SIDE-- DIODE	FWHM
G400H	4602.040	A	59.91	1.068		
	4627.477	A	51.43	1.063		
	4647.421	A	44.72	1.056		
G570H	4602.040	A			5.94	0.954
	4923.655	A			77.77	0.945
	4956.194	MIT2			85.11	0.957
	5039.156	A			103.51	0.931
	5081.797	A			113.03	0.920
	5249.025	MIT2			150.40	0.944
	5299.666	A	346.53	0.958		
	5402.063	A	323.07	0.925	184.50	0.923
	5406.507	MIT2			186.55	0.945
	5411.286	A	320.94	0.939		
	5749.896	A	243.40	0.933		
	5854.114	A	219.47	0.951	285.49	0.923
	5883.522	A	212.77	0.921	292.10	0.908
	5946.479	A	198.34	0.926	306.18	0.901
	6031.672	A	178.76	0.926		
	6076.024	A	168.57	0.911		
	6097.851	A	163.56	0.921		
	6144.763	A	152.81	0.931		
	6165.298	A	148.11	0.947		
	6219.003	A	135.77	0.944		
	6268.226	A	124.46	0.952		
	6306.536	A	115.67	0.949		
	6336.184	A	108.88	0.935		
	6384.757	A	97.72	0.937		
	6404.022	A	93.33	0.935		
	6508.330	A	69.38	0.961		
	6534.688	A	63.34	0.965		
	6600.775	A	48.15	0.963		
	6680.127	A	29.96	0.980		
	6718.897	A	21.07	0.987		
G780H	6306.536	A	509.50	1.056		
	6336.184	A	504.42	1.027		
	6384.757	A	496.02	1.041		
	6404.022	A	492.66	1.037		
	6508.330	A	474.56	1.011		
	6534.688	A	470.01	1.023		
	6600.775	A	458.49	1.006		
	6680.127	A	444.70	1.002		
	6718.897	A	437.97	1.004		
	6931.385	A	400.95	0.986		
	7034.353	A	383.01	0.998		
	7175.920	A	358.34	0.972		
	7247.170	A	345.90	0.979		
	7440.953	A	312.08	0.997		
	7490.937	A	303.38	0.994		
	8302.612	A	161.49	0.995		
	8420.745	A	140.85	0.981		
	8497.699	A	127.44	0.995		

Table 2 (continued).

			--RED SIDE--		--BLUE SIDE--	
DISPERSER	VACUUM	REF	DIODE	FWHM	DIODE	FWHM
G160L	1971.621	A			437.52	1.066
	2085.969	A	48.66	1.127	453.99	0.953
	2144.922	A	40.05	1.030	462.48	0.941
	2175.352	A	35.58	1.125	466.92	0.977
	2202.816	A			470.83	0.928
	2275.083	A			479.59	0.993
	2440.797	A			505.16	1.124
	2468.688	A			509.27	1.110
	2487.919	A			512.12	1.044
G650L	~5039	MIT2			356.15	0.980
	~5082	MIT2			357.80	0.933
	5209.872	A	141.47	0.972	362.88	0.917
	~5402	MIT2			370.57	0.932
	5854.114	A	115.27	0.955	388.50	0.914
	5946.479	A	111.48	0.973		
	6031.672	A	108.05	0.984		
	~6219	EST	100.45	0.973		
	6268.226	A	98.45	0.977		
	6600.775	A	84.96	0.950		
	6680.127	A	81.72	0.942		
	6718.897	A	80.19	0.964		
	6931.385	A	71.52	0.937		
	7034.353	A	67.40	0.957		
	7175.920	A	61.59	0.979		
	7247.170	A	58.73	0.933		
	7440.953	A	50.88	0.970		
PRISM	1916.082	RAS			164.71	0.884
	2050.048	RAS			139.76	0.778
	~2085	RAS	375.95	1.024	134.31	0.874
	2129.282	A	382.38	1.114	128.10	0.975
	2144.916	A	384.39	0.974	126.08	0.875
	2175.352	A	388.38	0.987	122.15	0.980
	~5782	EST			26.93	0.941

References:
A - Sirk and Bohlin (1986)
RAS - Reader, Acquista, and Sansonetti (1988)
MIT2 - Phelps (1982)
EST - Estimated from dispersion constants in Kriss, et al. (1988)

Table 3. Rejected Lines from the Wavelength Calibration Line Library

GRATING	VACUUM	REF.*	COMMENTS
G190H	2165.872	RAS(.8905)	Blend w/ 2165.8203 (30%)**
	2191.000	RAS(.0062)	Blend w/ 2190.8651 (20%)
	2246.215	RAS(.2233)	Blend w/ 2247.2183 (30%), 2245.6736 (15%), obvious visual asymmetry
	2263.363	RAS(.4181)	Blend; sum of lines in 1.8 diode window > 20%
	2275.083	RAS(.0843)	Blend; sum of lines in 1.8 diode window > 60%
	2319.007	RAS(.0092)	Blend; 2320.6011 + 2318.7204 > 40%
G270H	2235.610	RAS(.6204)	
	2263.363	RAS(.4181)	
	2275.083	RAS(.0843)	
	2319.007	RAS(.0092)	
	2340.894	RAS(.8977)	
	2487.919	RAS(.9192)	
	2628.815	RAS(.8107)	
	2640.132	RAS(.1310)	
	2734.770	RAS(.7659)	
	2763.736	RAS(.7380)	
	2772.490	RAS(.4778)	
	2876.693	RAS(.4778)	
G400H	3310.732	RAS(.6925)	
	3409.107	RAS(.1086)	
	3418.880	RAS(.8832)	
	3473.564	RAS(.5645)	
	3569.549	RAS(.5212)	
	3594.575	RAS(.5506)	
	3665.154	RAS(.1232)	
	3819.774	RAS(.7753)	
G570H	5265.627	MIT2	Cr I (4 lines between 5263.218 and 5267.188. Strongest is 5265.617); Pt 5262.30.
G160L	1916.083	RAS(.0818)	Blend w/ 1911.7097 (50%)

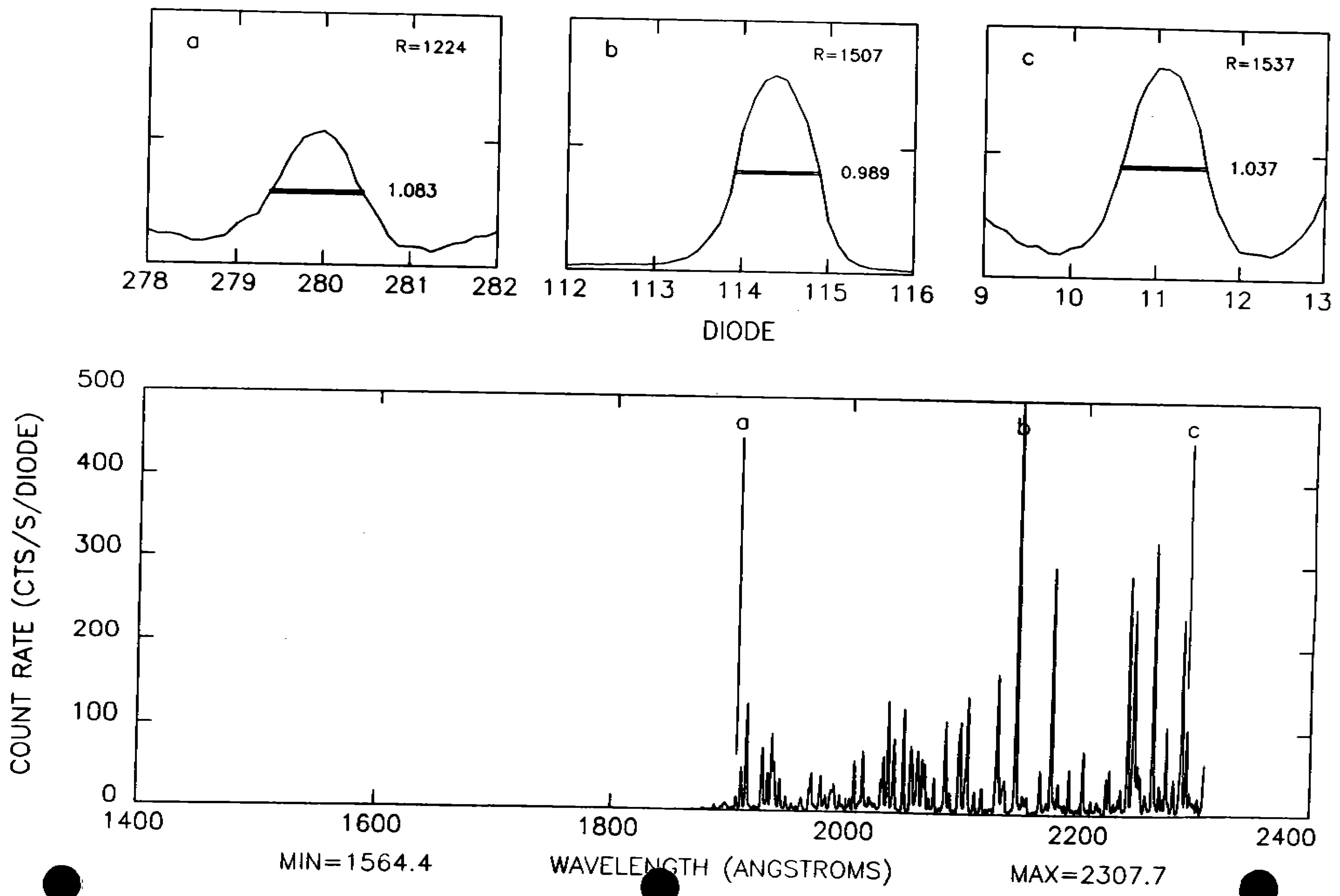
* - The wavelength decimal fraction, as indicated in RAS, shown in ().
** - Intensity contribution of blended line, per RAS.
MIT2 - M.I.T. Wavelength tables, Vol. 2, 1982.
RAS - Platinum/Neon Master List: Reader, Acquista, Sansonetti, 29 Jun 88.

Table 4. Possible Line Library Additions

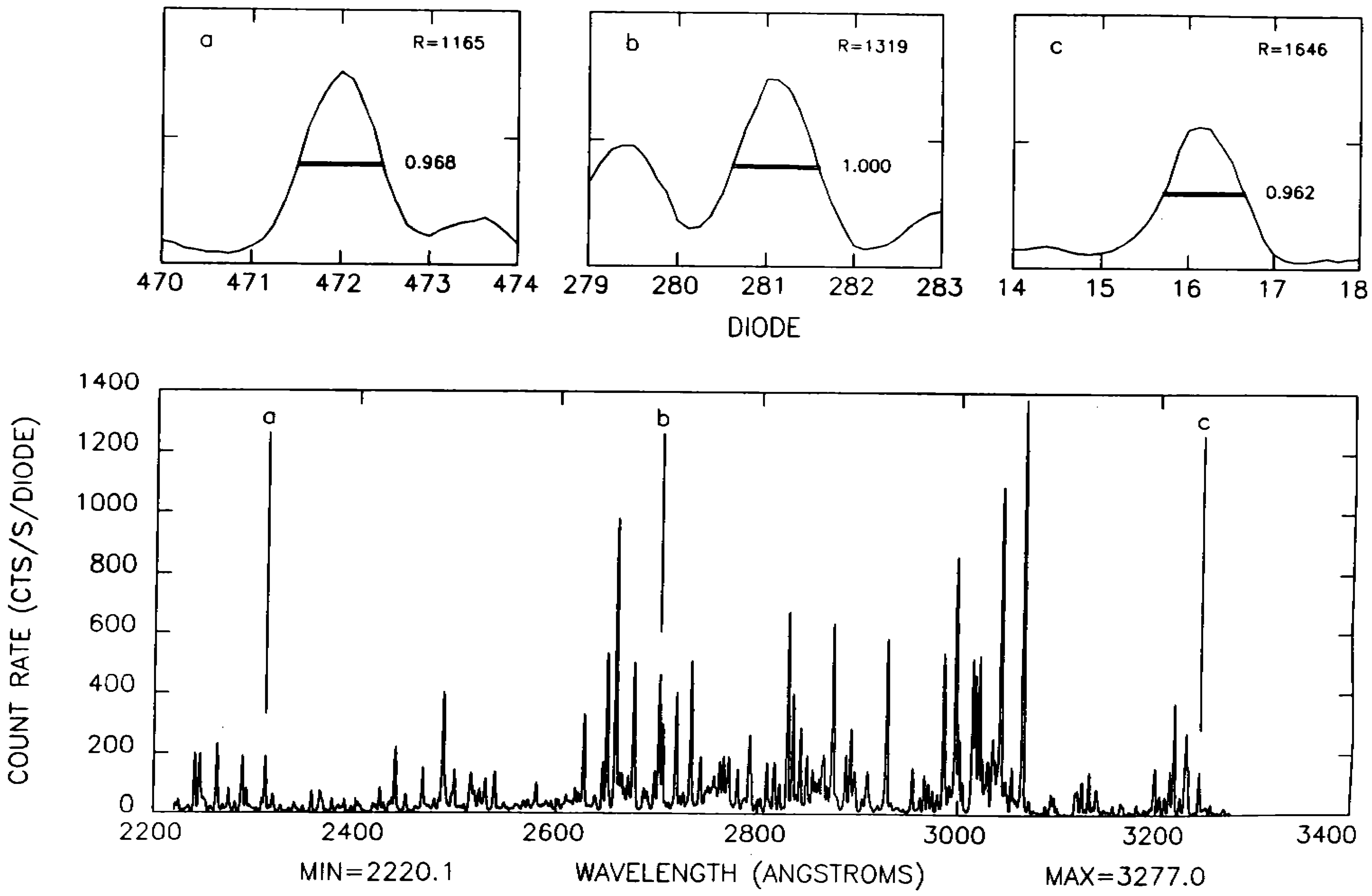
DISPERSER	SIDE	VACUUM	DIODE	REF.	COMMENTS
G190H	BLUE	1934.3690	245.65	RAS	
		1954.7444	259.53	RAS	
		2008.4064	295.99	RAS	
		2210.1932	433.53	RAS	
		2269.5399	474.38	RAS	
	RED	1934.3690	261.28	RAS	
		1949.9096	250.48	RAS	A 'tight' blend with 1949.8139 (60%)
		2008.4064	209.62	RAS	
		2015.5834	204.61	RAS	
		2210.1932	68.86	RAS	
		2269.5399	27.50	RAS	
G270H	BOTH	2647.6686	200.17	RAS	
G400H	BLUE	4956.194	85.11	MIT2	Cr
		5249.025	150.40	MIT2	CrI
		5406.507	186.55	MIT2	Cr
G650L	BLUE	~5039	356.15	MIT2	Many Pt and Ne lines within a 1.8 diode window.
		~5082	357.80	MIT2	
		~5402	388.50	MIT2	
	RED	~5210	141.47	none	
		~6219	100.45	none	
PRISM	BLUE	1916.0818	164.71	RAS	Ne II, a clean line.
		2050.0484	139.76	RAS, MIT2	Pt I, blending with ~20% of intensity of central line contributed from nearby Pt I lines.
		~2085	134.31	RAS, MIT2	Pt I, plenty of nearby Pt I lines.
		~5782	26.93	MIT2	Ne II (5854.1 is strongest). Plenty of Pt,Cr,Ne
	RED	~2085	375.95	RAS, MIT2	Same as Blue

References:
MIT2 - M.I.T. Wavelength tables, Vol. 2, 1982.
RAS - Platinum/Neon Master List: Reader, Acquista, Sansonetti, 29 Jun 88.

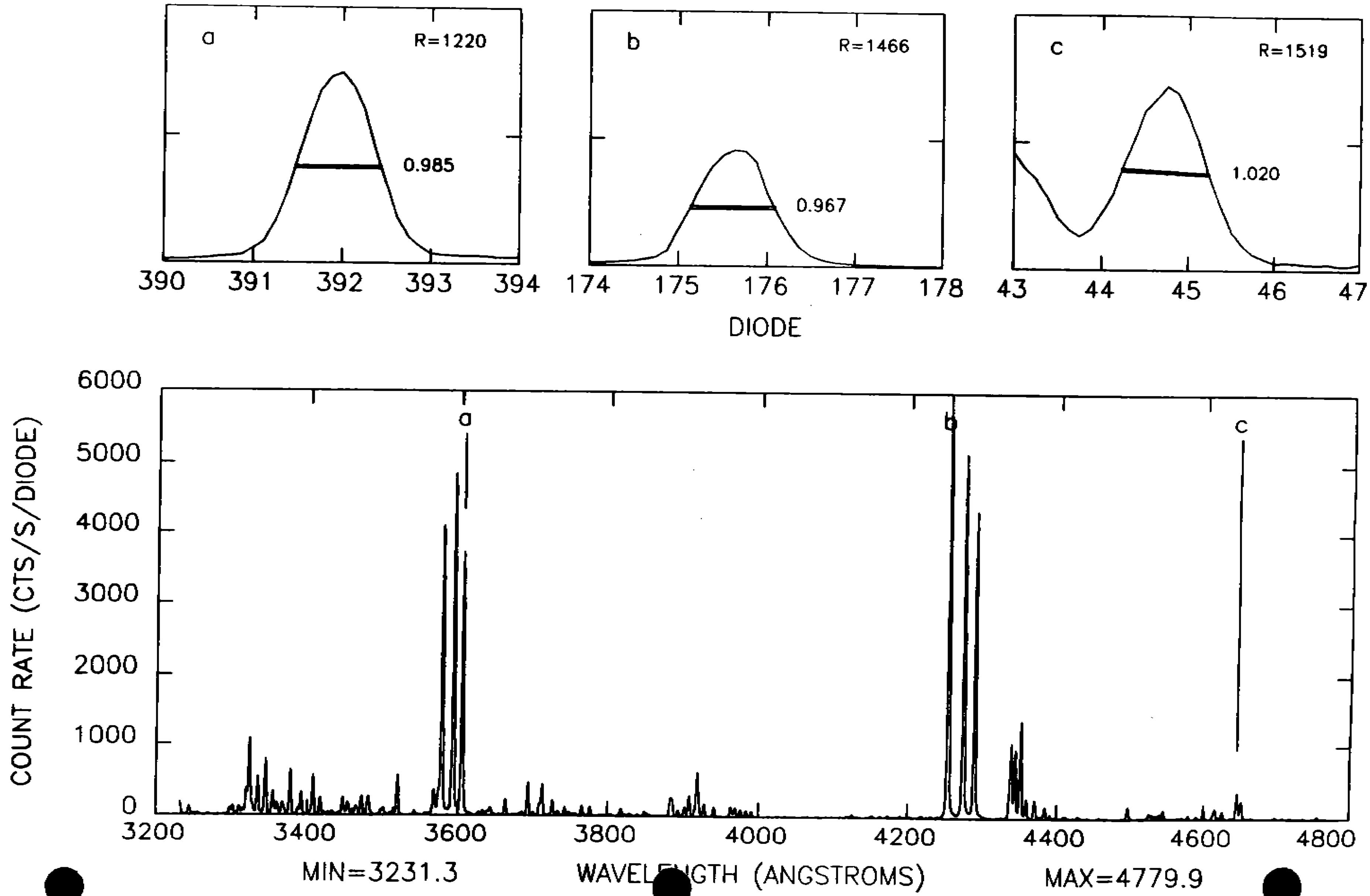
FOS Resolution and Spectral Range: H19 Red Side



FOS Resolution and Spectral Range: H27 Red Side



FOS Resolution and Spectral Range: H40 Red Side



FOS Resolution and Spectral Range: H57 Red Side

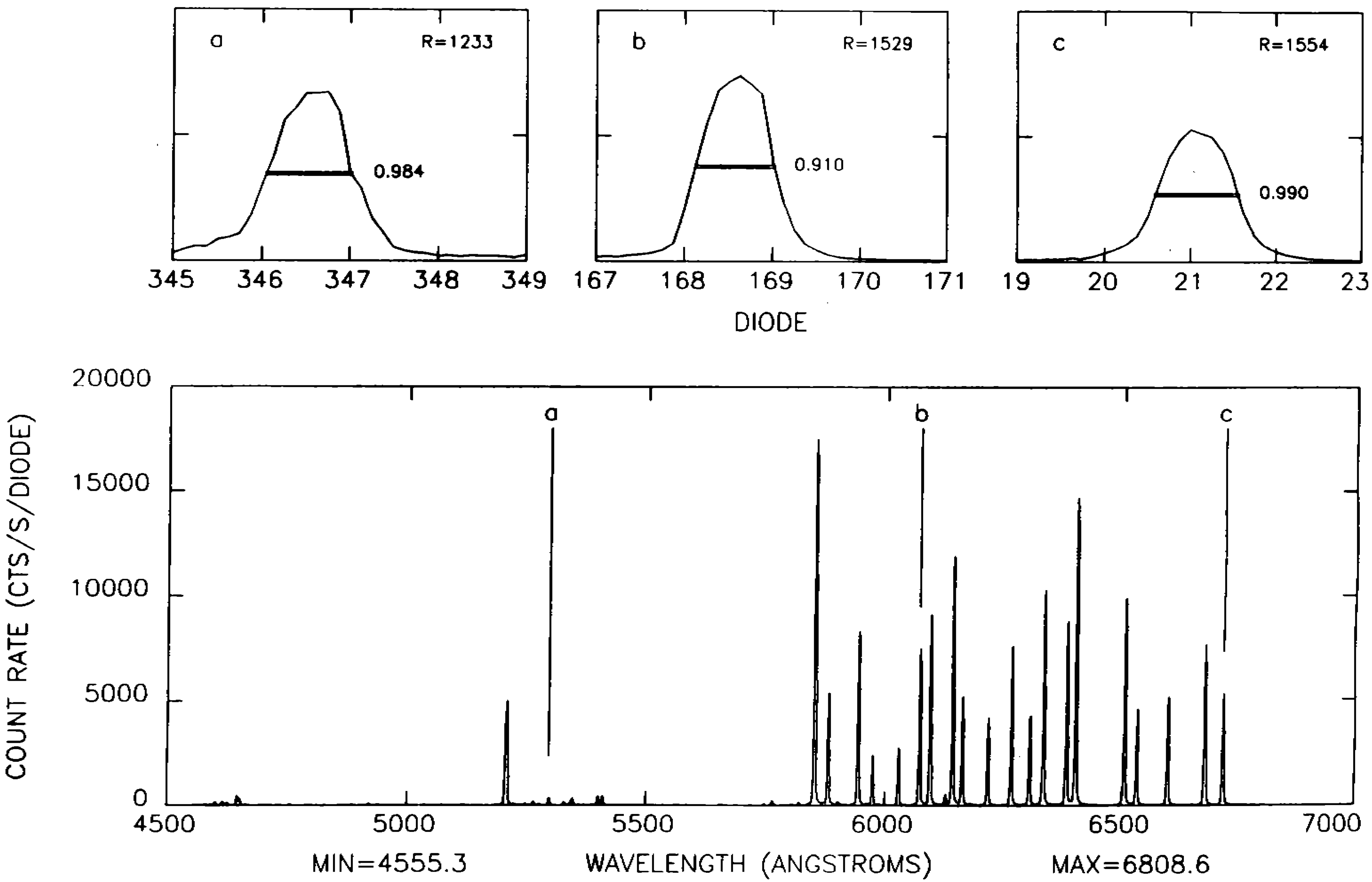
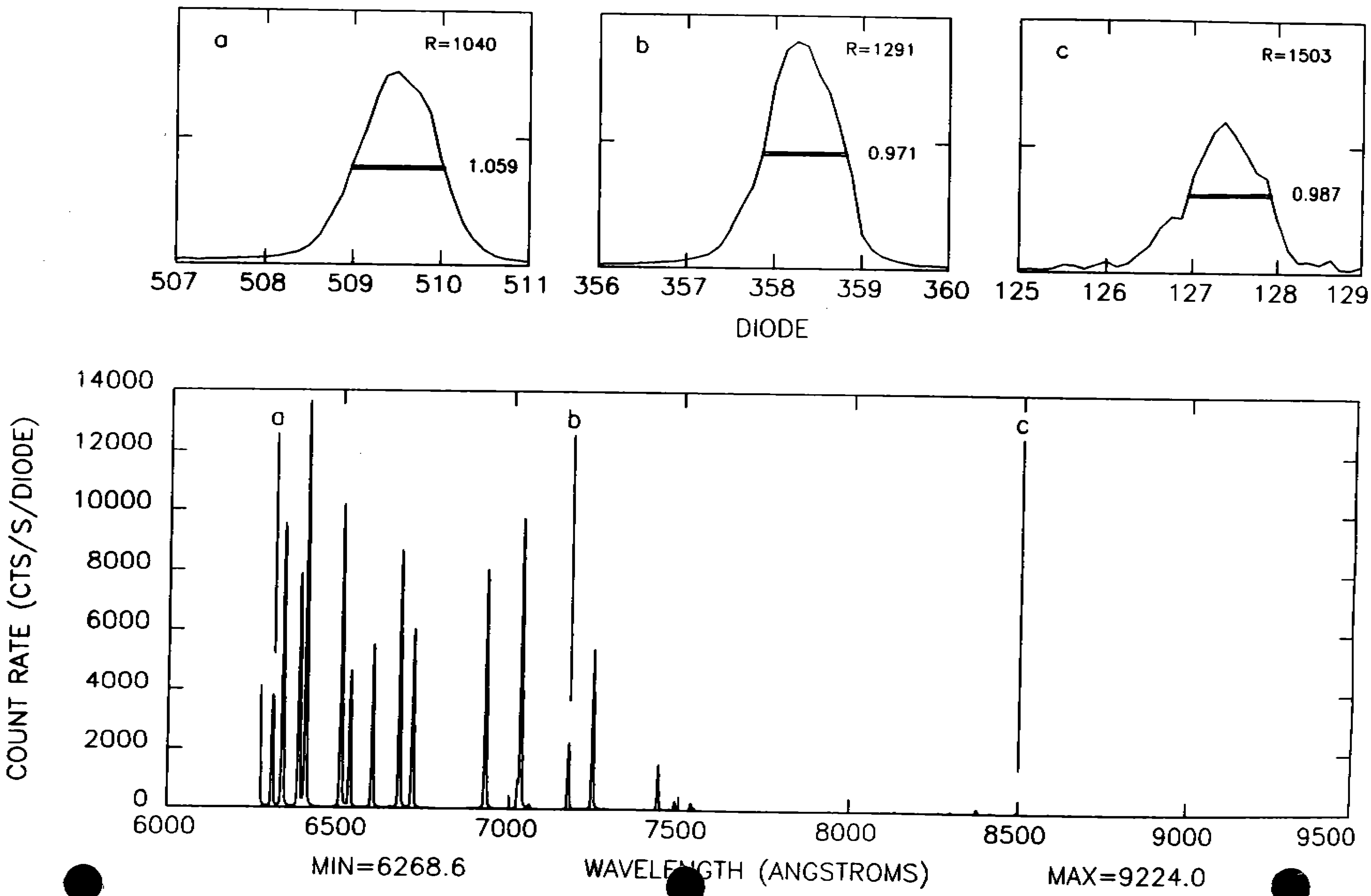
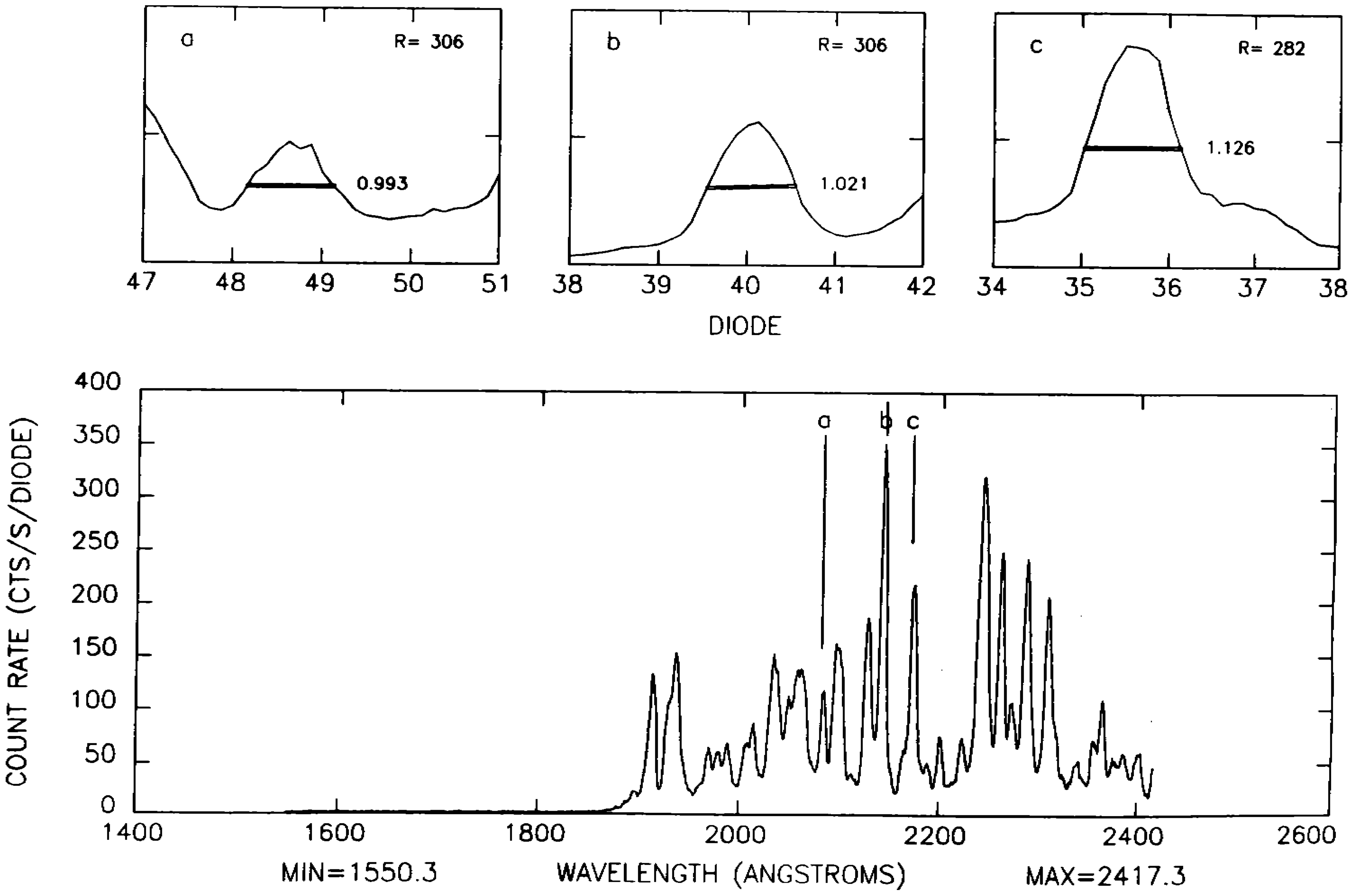


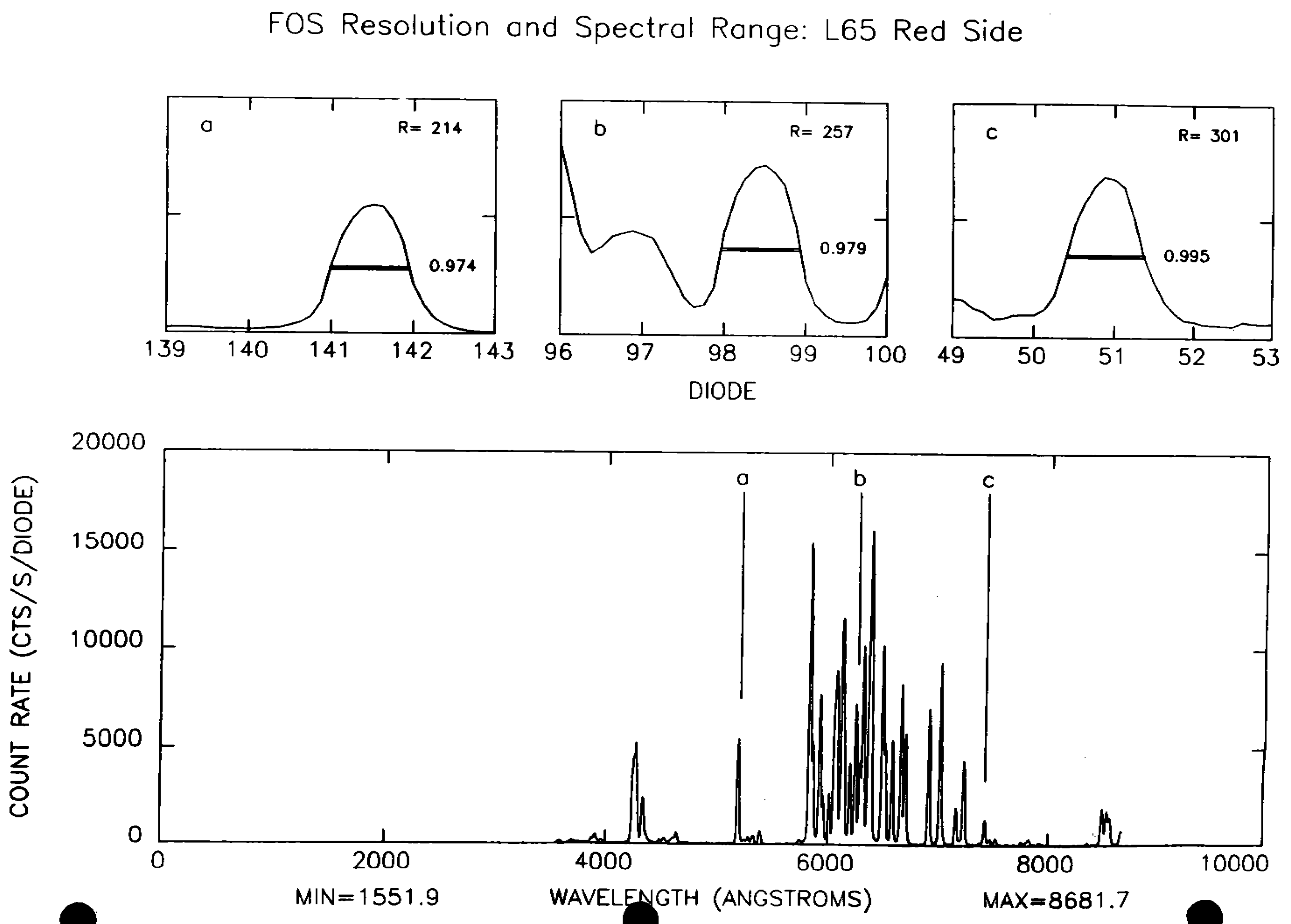
Fig 1d

FOS Resolution and Spectral Range: H78 Red Side

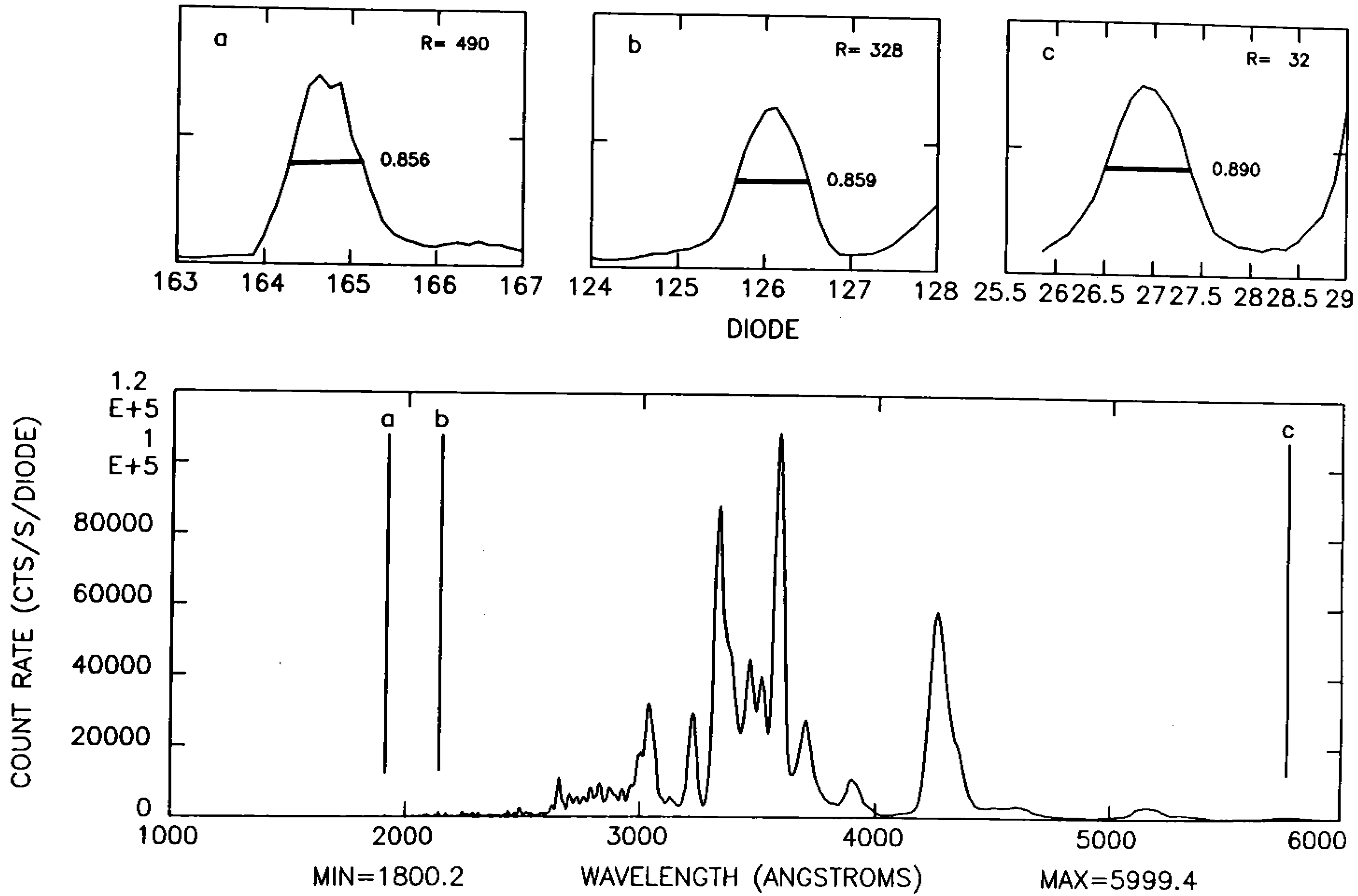


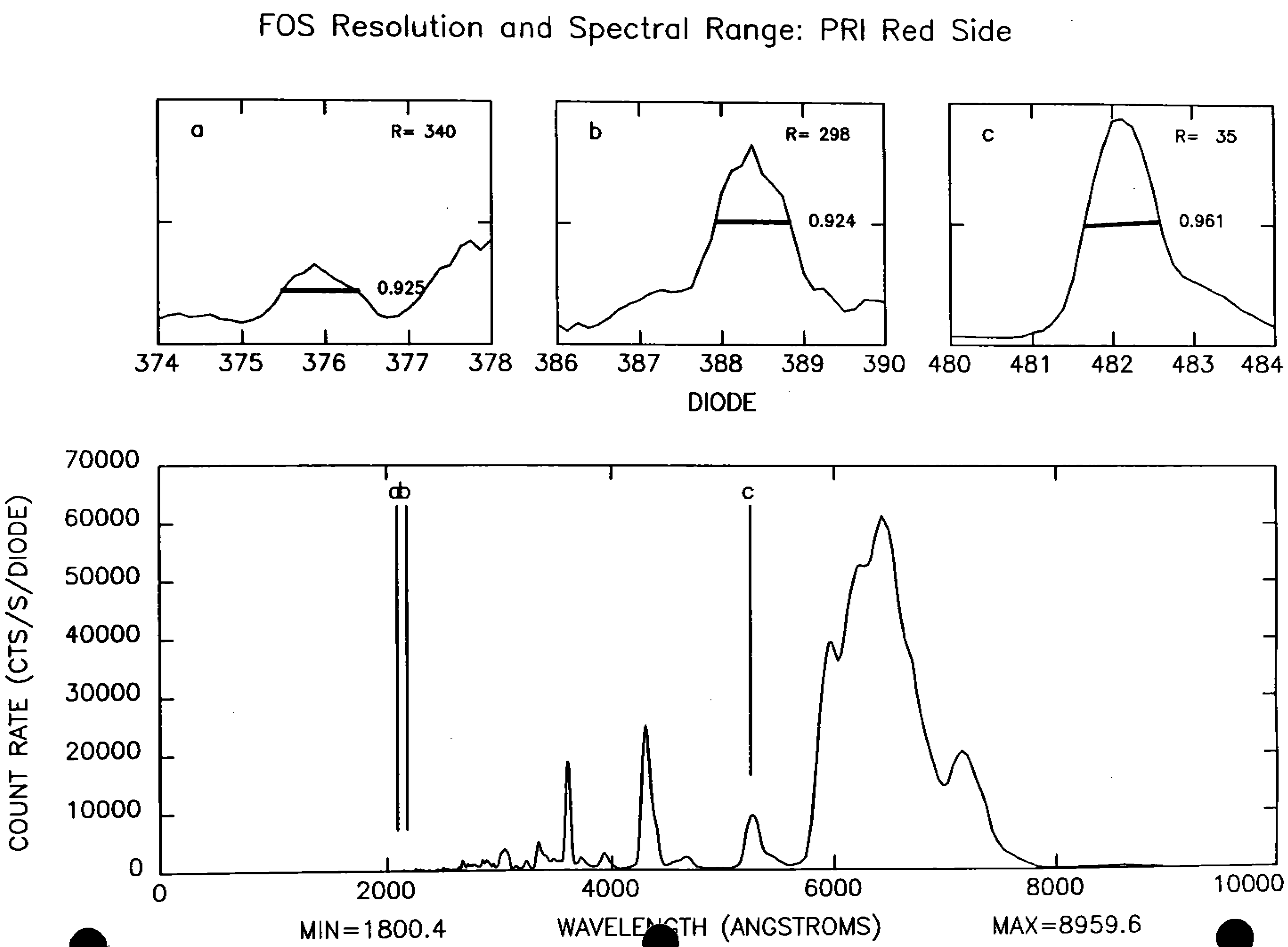
FOS Resolution and Spectral Range: L15 Red Side



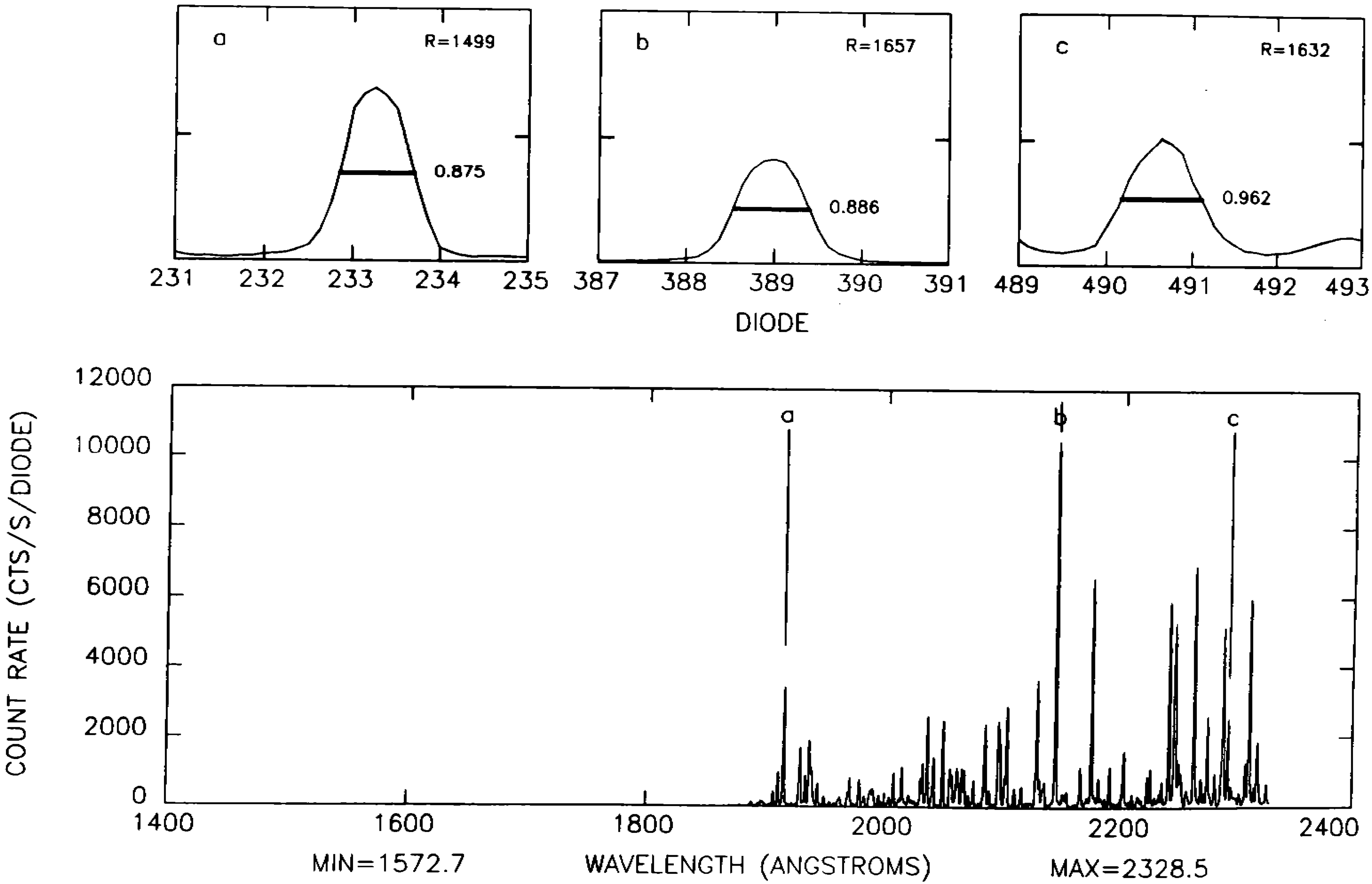

FOS Resolution and Spectral Range: L65 Red Side
a
R= 214
0.974
139
140
141
142
143
b
R= 257
0.979
96
97
98
99
100
c
R= 301
0.995
49
50
51
52
53
DIODE
COUNT RATE (CTS/S/DIODE)
20000
15000
10000
5000
0
2000
4000
6000
8000
10000
MIN=1551.9
WAVELENGTH (ANGSTROMS)
MAX=8681.7

FOS Resolution and Spectral Range: PRI Blue Side

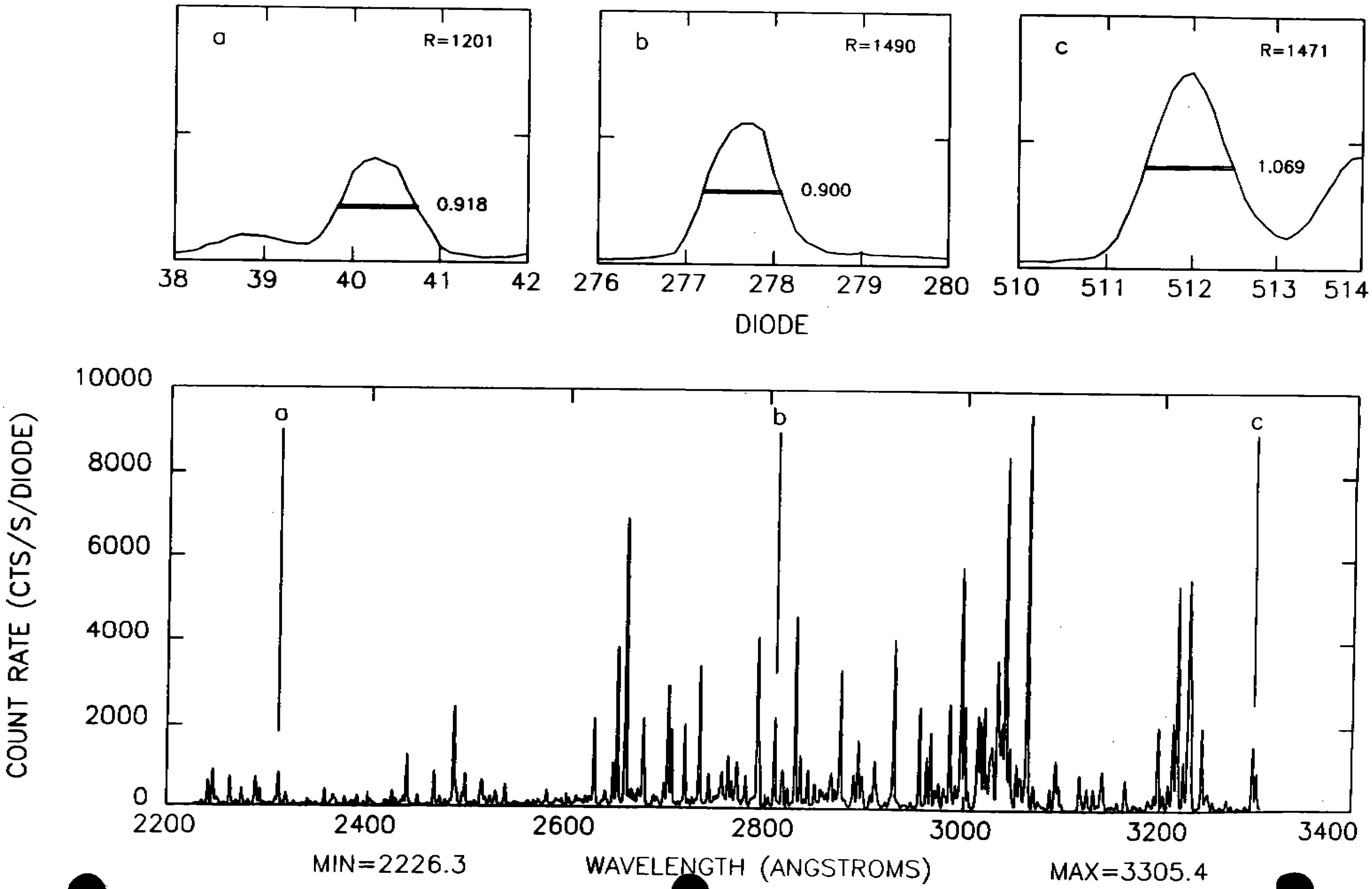



FOS Resolution and Spectral Range: PRI Red Side
a
R= 340
0.925
b
R= 298
0.924
c
R= 35
0.961
374
375
376
377
378
386
387
388
389
390
480
481
482
483
484
DIODE
70000
60000
50000
40000
30000
20000
10000
0
COUNT RATE (CTS/S/DIODE)
ab
c
0
2000
4000
6000
8000
10000
MIN=1800.4
WAVELENGTH (ANGSTROMS)
MAX=8959.6

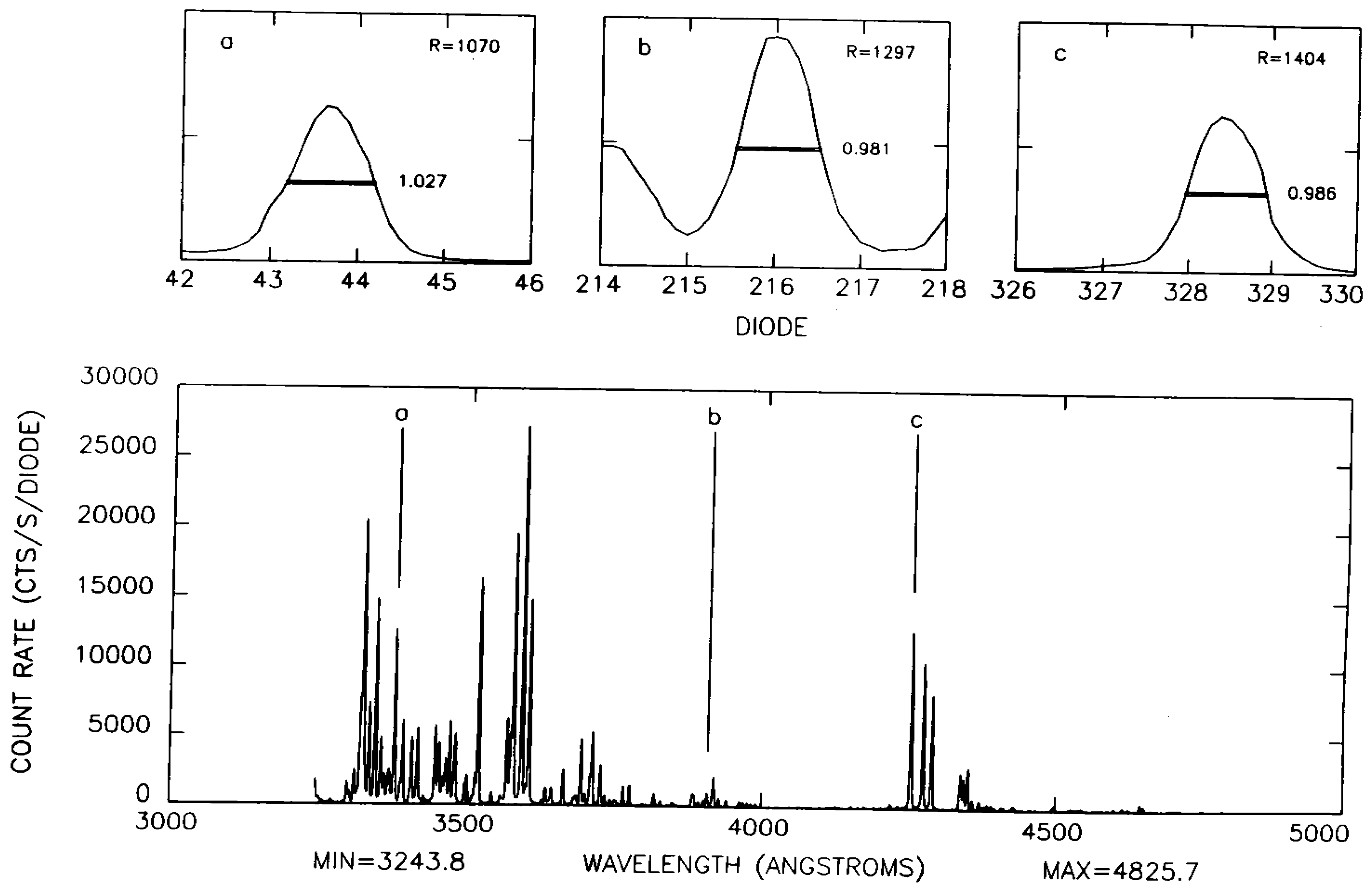
FOS Resolution and Spectral Range: H19 Blue Side



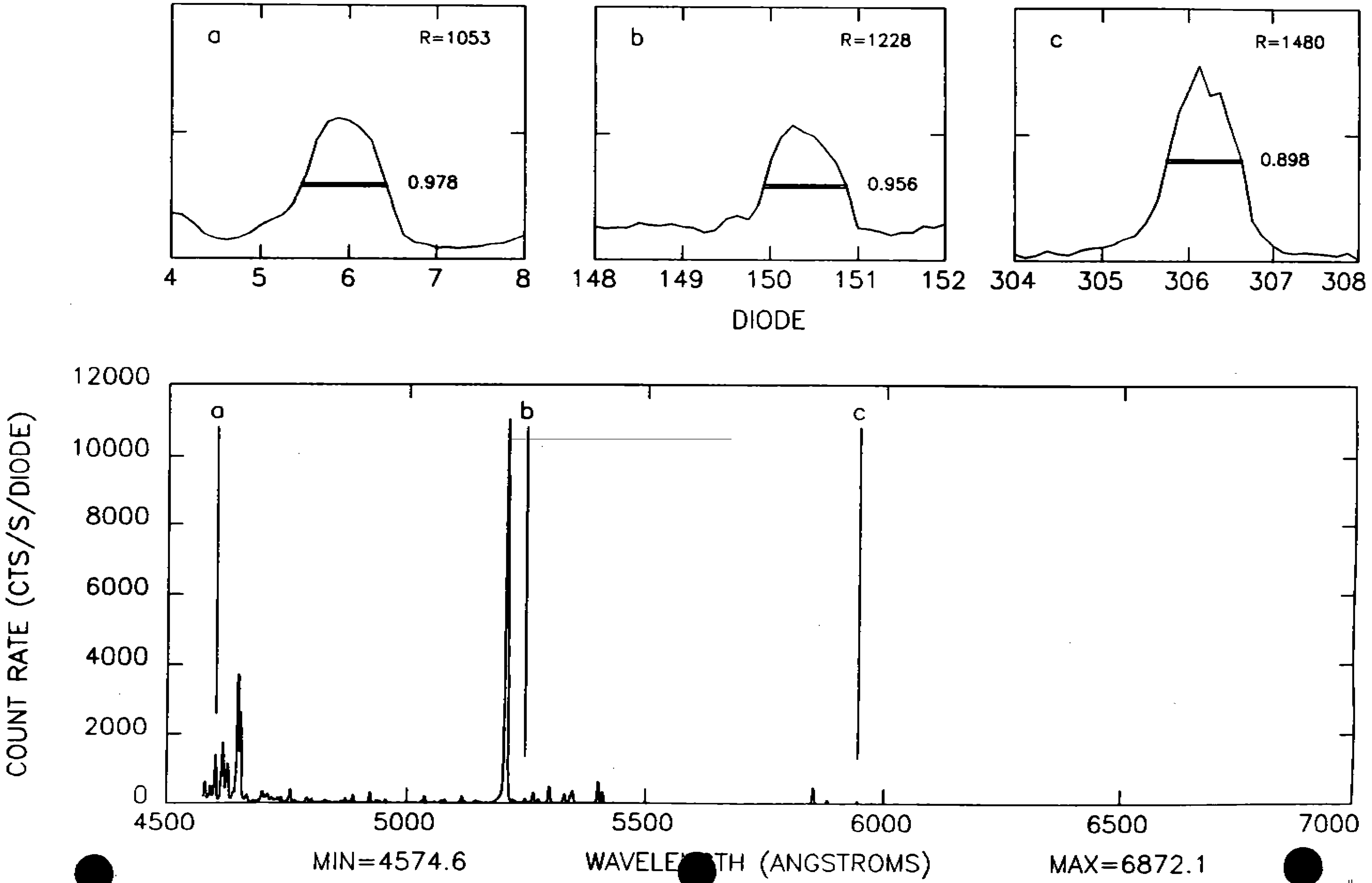
FOS Resolution and Spectral Range: H27 Blue Side



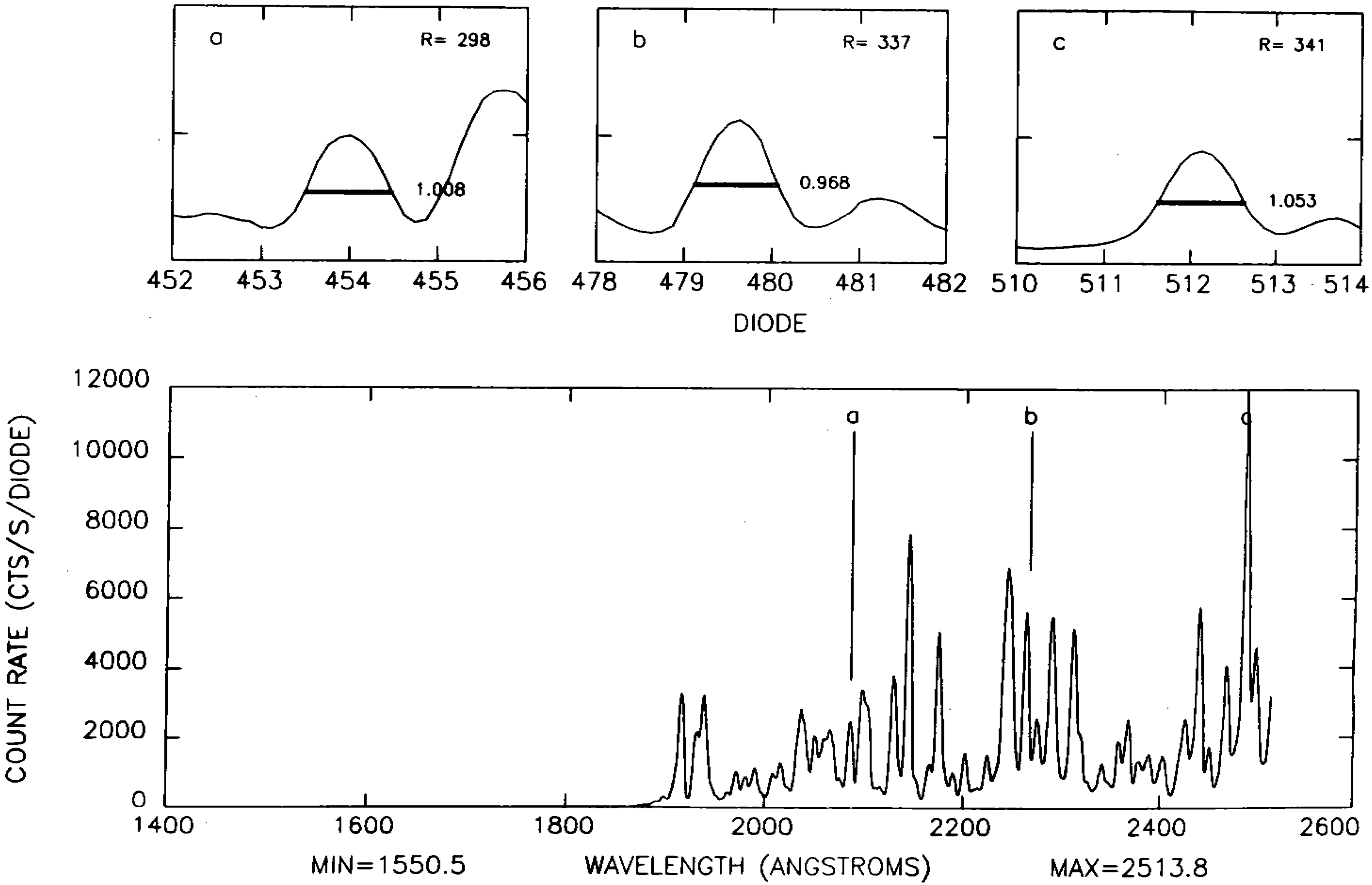
FOS Resolution and Spectral Range: H40 Blue Side



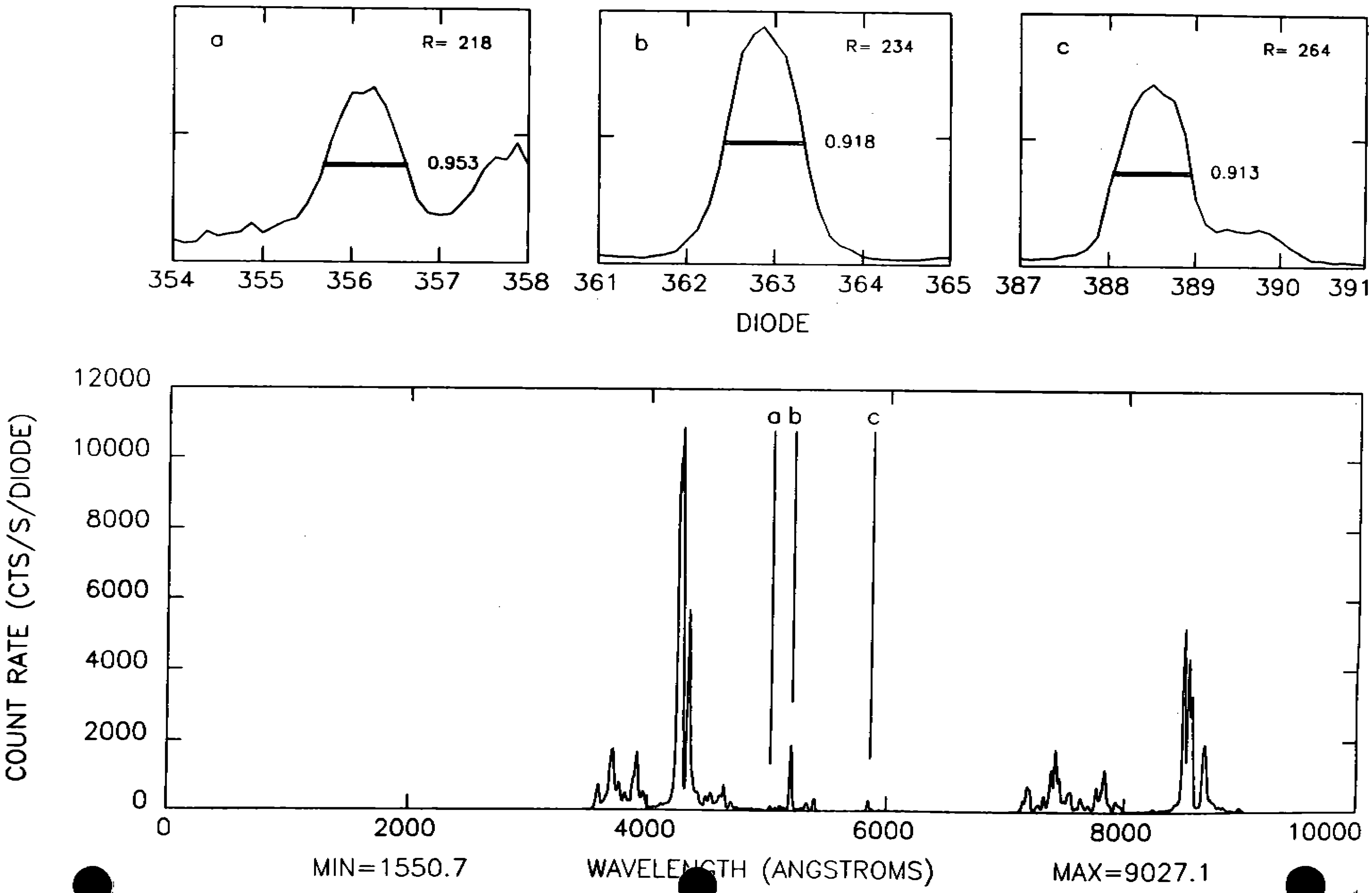
FOS Resolution and Spectral Range: H57 Blue Side

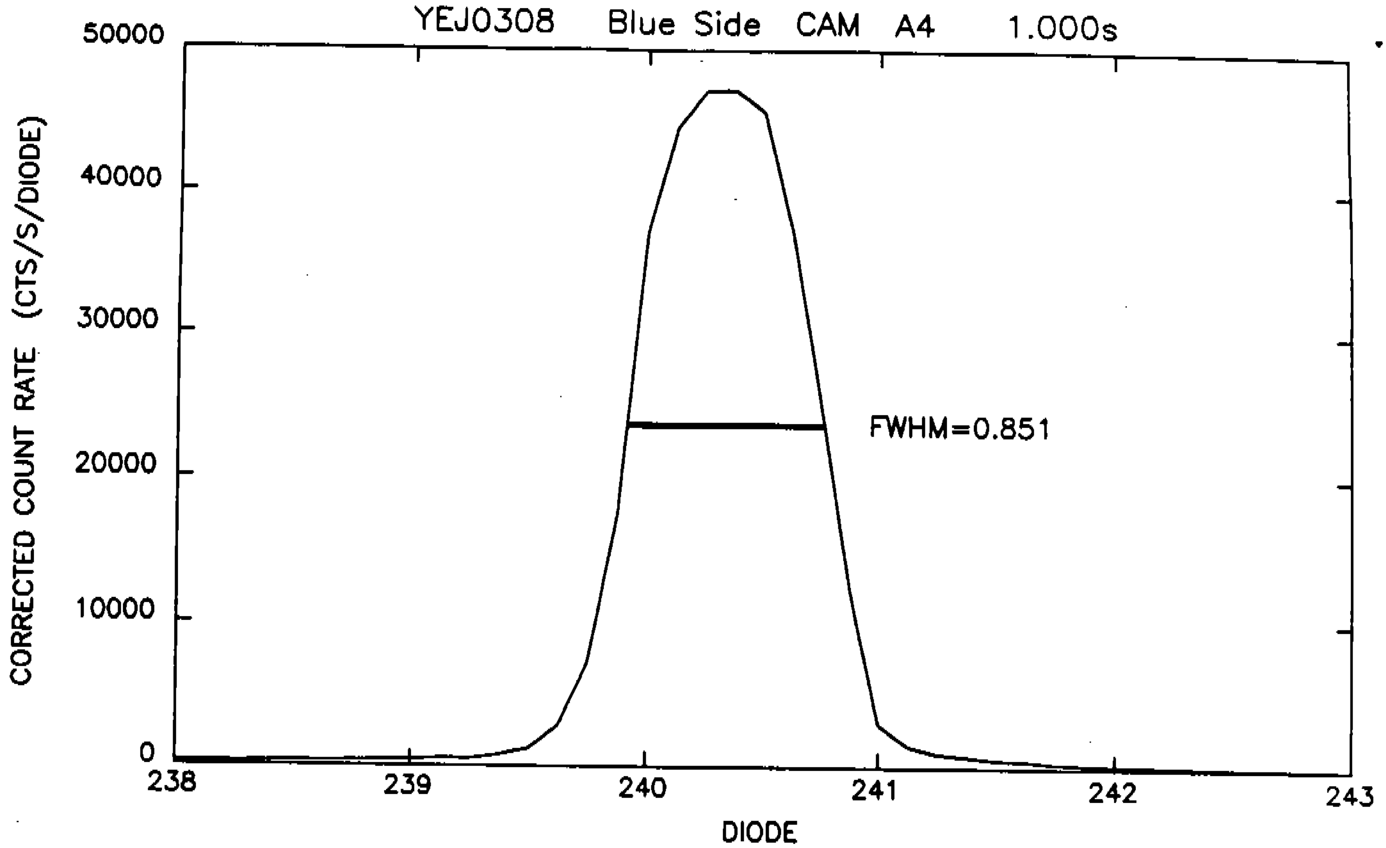


FOS Resolution and Spectral Range: L15 Blue Side



FOS Resolution and Spectral Range: L65 Blue Side




YEJ0308 Blue Side CAM A4 1.000s
CORRECTED COUNT RATE (CTS/S/DIODE)
50000
40000
30000
20000
10000
0
FWHM=0.851
238
239
240
241
242
243
DIODE

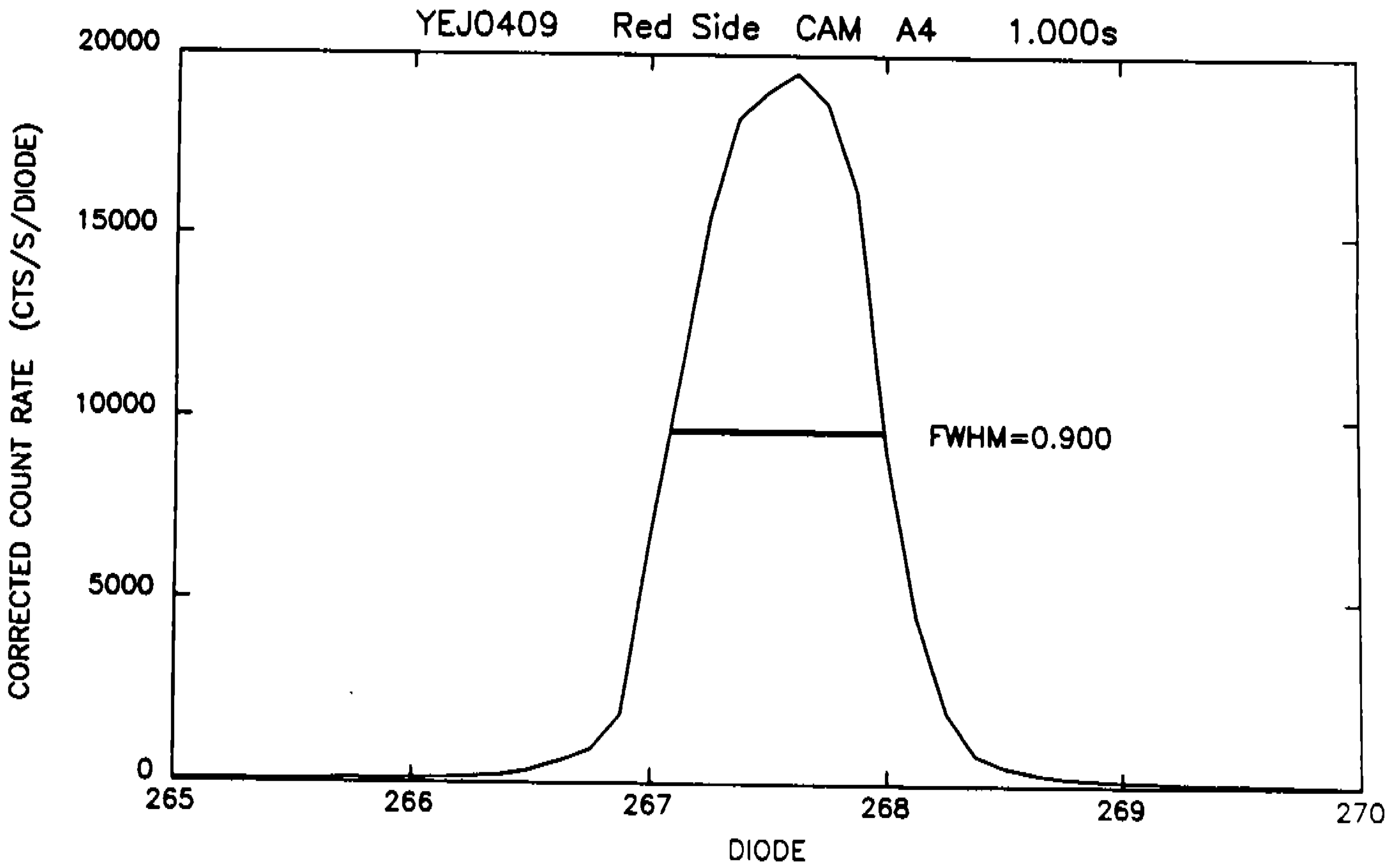
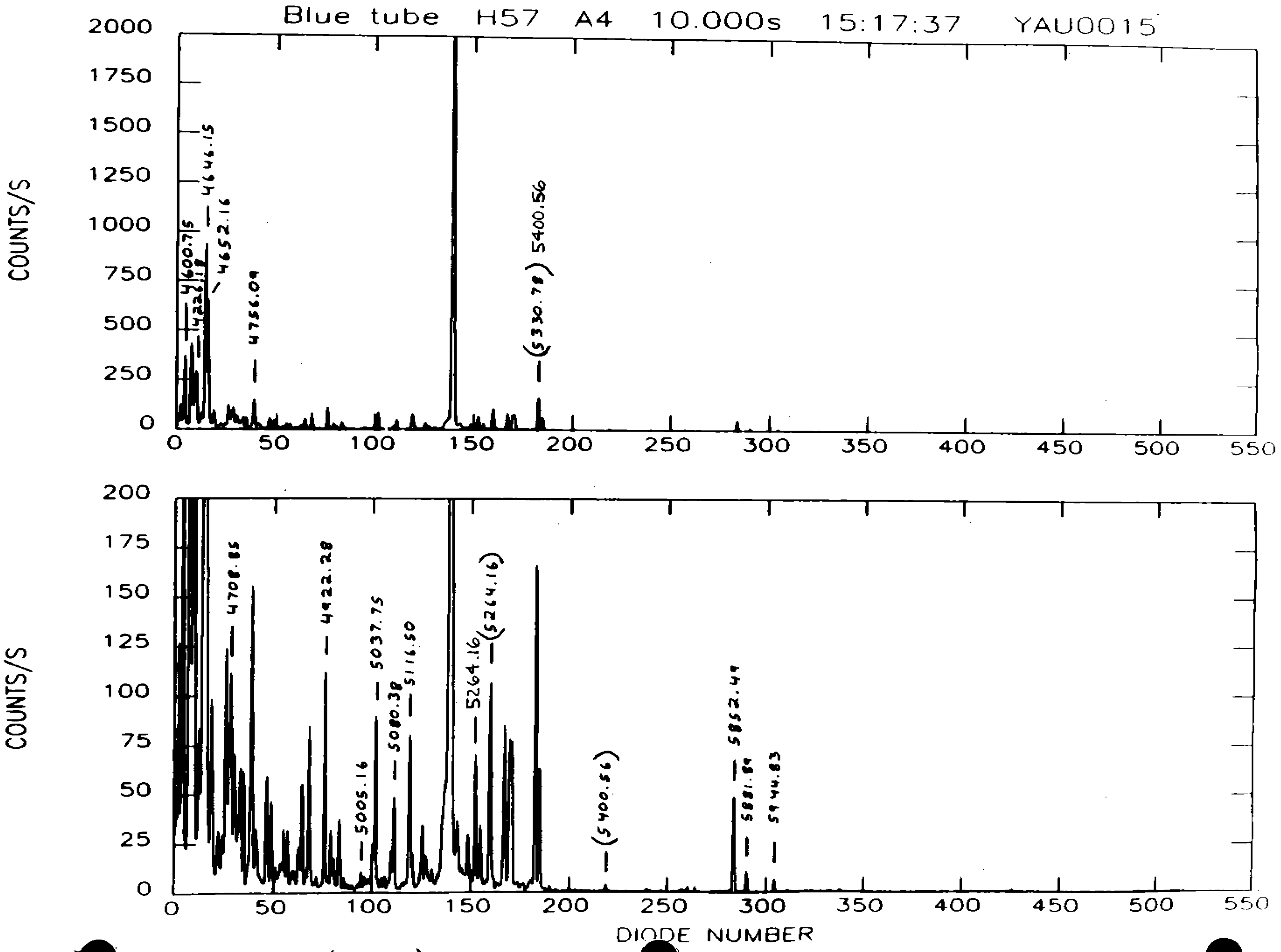

YEJ0409 Red Side CAM A4 1.000s
CORRECTED COUNT RATE (CTS/S/DIODE)
20000
15000
10000
5000
0
FWHM=0.900
265
266
267
268
269
270
DIODE

Fig 2



Blue tube H57 A4 10.000s 15:17:37 YAU0015
COUNTS/S
2000
1750
1500
1250
1000
750
500
250
0
4600.75
4226.18
4646.15
4652.16
4756.09
(5330.78) 5400.56
0
50
100
150
200
250
300
350
400
450
500
550
COUNTS/S
200
175
150
125
100
75
50
25
0
4708.85
4922.28
5005.16
5037.75
5080.38
5116.50
5264.16
(5264.16)
(5400.56)
5852.49
5881.84
5944.83
DIODE NUMBER

(Figure 2e.)